

29466 Intake  
R4-NC-Brunswick

# **Brunswick Steam Electric Plant**

## **1999 Environmental Monitoring Report**

**Environmental Services Section**



**BRUNSWICK STEAM ELECTRIC PLANT  
1999 BIOLOGICAL MONITORING REPORT**

Prepared by:

Environmental Services Section

CAROLINA POWER & LIGHT COMPANY

New Hill, North Carolina

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## Preface

This copy of the report is not a controlled document as detailed in the *Environmental Services Section Biology Program Procedures Manual and Quality Assurance Manual*. Any changes made to the original of this report subsequent to the date of issuance can be obtained from:

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## Metric-English Conversion and Units of Measure

### Length

1 micron ( $\mu\text{m}$ ) =  $4.0 \times 10^{-5}$  inch  
 1 millimeter (mm) = 0.001 m = 0.04 inch  
 1 centimeter (cm) = 10 mm = 0.4 inch  
 1 meter (m) = 100 cm = 3.28 feet  
 1 kilometer (km) = 1000 m = 0.62 mile

### Volume

1 milliliter (ml) = 0.034 fluid ounce  
 1 liter = 1000 ml = 0.26 gallon  
 1 cubic meter = 35.3 cubic feet

### Area

1 square meter ( $\text{m}^2$ ) = 10.76 square feet  
 1 hectare (ha) = 10,000  $\text{m}^2$  = 2.47 acres

### Weight

1 microgram ( $\mu\text{g}$ ) =  $10^{-3}$  mg or  
 $10^{-6}$  g =  $3.5 \times 10^{-8}$  ounce  
 1 milligram (mg) =  $3.5 \times 10^{-5}$  ounce  
 1 gram (g) = 1000 mg = 0.035 ounce  
 1 kilogram (kg) = 1000 g = 2.2 pounds  
 1 metric ton = 1000 kg = 1.1 tons  
 1 kg/hectare = 0.89 pound/acre

### Temperature

Degrees Celsius ( $^{\circ}\text{C}$ ) =  $5/9$  ( $^{\circ}\text{F} - 32$ )

## Common and Scientific Names of Species Used in This Report

Threadfin shad	<i>Dorosoma petenense</i>	Southern flounder	<i>Paralichthys lethostigma</i>
Atlantic menhaden	<i>Brevoortia tyrannus</i>	Shrimp	<i>Penaeus</i> spp.
Anchovies	<i>Anchoa</i> spp.	Brown shrimp	<i>P. aztecus</i>
Bay anchovy	<i>A. mitchilli</i>	Pink shrimp	<i>P. duorarum</i>
Striped anchovy	<i>A. hepsetus</i>	White shrimp	<i>P. setiferus</i>
Oyster toadfish	<i>Opsanus tau</i>	Hardback shrimp	<i>Trachypenaeus</i> spp.
Silversides	<i>Atherinidae</i>	Swimming crab larvae	Portunid megalops
Pinfish	<i>Lagodon rhomboides</i>	Blue crabs	<i>Callinectes</i> spp.
Star drum	<i>Stellifer lanceolatus</i>	Blue crab	<i>C. sapidus</i>
Silver perch	<i>Bairdiella chrysura</i>	Lesser blue crab	<i>C. similis</i>
Spotted seatrout	<i>Cynoscion nebulosus</i>		
Spot	<i>Leiostomus xanthurus</i>		
Croaker	<i>Micropogonias undulatus</i>		
Gobies	<i>Gobiosoma</i> spp.		
Gobies	<i>Gobionellus</i> spp.		

## Executive Summary

Biological monitoring of the Cape Fear Estuary (CFE) at Carolina Power & Light Company's (CP&L) Brunswick Steam Electric Plant (BSEP) was conducted in 1999 as part of the National Pollutant Discharge Elimination System (NPDES) permit requirements. Entrainment and impingement studies monitored the effectiveness of the intake modifications in reducing entrainment and impingement of fish and shellfish.

Use of fine-mesh screens reduced the number of organisms and the number of taxa entrained. The number of taxa entrained was reduced by 21 from a total of 55 taxa impinged. All 55 taxa would have been entrained without the use of fine-mesh traveling screens. Depending upon taxa, entrainment of all organisms combined was reduced by approximately 19%, with a range of 2% to 39%, by using fine-mesh screens in 1999. Reductions in the entrainment of organisms during 1999 were less than previous years due to operation with a greater number of coarse-mesh screen panels. Based on survival estimates data, approximately 22% of all larval species impinged were returned alive to the estuary. Due to the effects of three hurricanes coupled with using less fine-mesh screens, fewer shrimp and crab larvae (taxa exhibiting high survival in the fish return system) were impinged during 1999 resulting in lower overall survival compared to survival during 1998. Recurring hurricanes and associated increased sedimentation rates during recent years have contributed to operability problems with the fine-mesh traveling screens. Dredging of the intake canal is underway in an effort to restore full operability of the fine-mesh traveling screens.

The juvenile and adult impingement catch for 1999 was numerically dominated by bay anchovy and white shrimp. Prior to 1983, larger fin fish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 1999 continued to show a shift towards impingement of smaller individuals for most of the selected species as a result of the construction of the diversion structure and the use of fine-mesh screens. This is important because it is the larger individuals which comprise the reproducing members of the population. Results of time-series analysis on 23 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Ten out of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities from 1977 through 1999. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline. Based on survival estimates, approximately 76% of the total number and 73% of the total weight of the impinged organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the juvenile and adult blue crabs and approximately 87% to 94% of the shrimp were returned alive to the estuary. These were the most valuable commercial species.

Biological monitoring during 1999 continued to show that the combination of the diversion structure, fine-mesh screens, and the fish return system reduced the number of entrained and impinged fish and shellfish. These modifications also continued to ensure that the most valuable commercial species are returned alive to the estuary in large numbers.

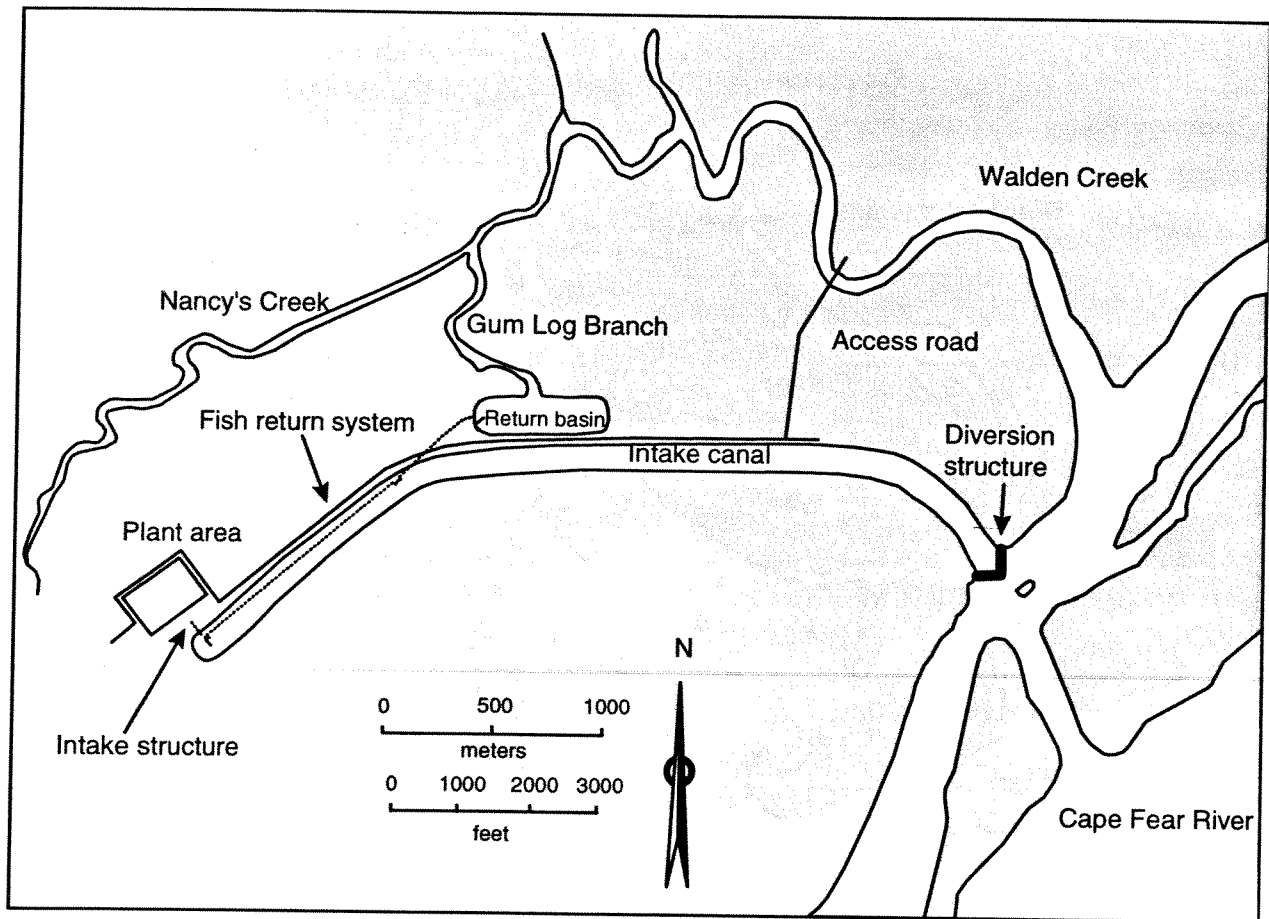
## 1.0 INTRODUCTION

Carolina Power & Light Company was issued a permit in December 1974 to discharge cooling water from the BSEP into the Atlantic Ocean under a NPDES permit. Cooling water is withdrawn from the Cape Fear River (CFR). As a stipulation of the NPDES permit, biological monitoring is required to provide sufficient information for a continuing assessment of power plant impacts on the marine and estuarine fisheries of the CFE. Data are reported annually and will provide an assessment of the effectiveness of the fish diversion structure and fine-mesh screens in minimizing the entrainment and impingement of organisms.

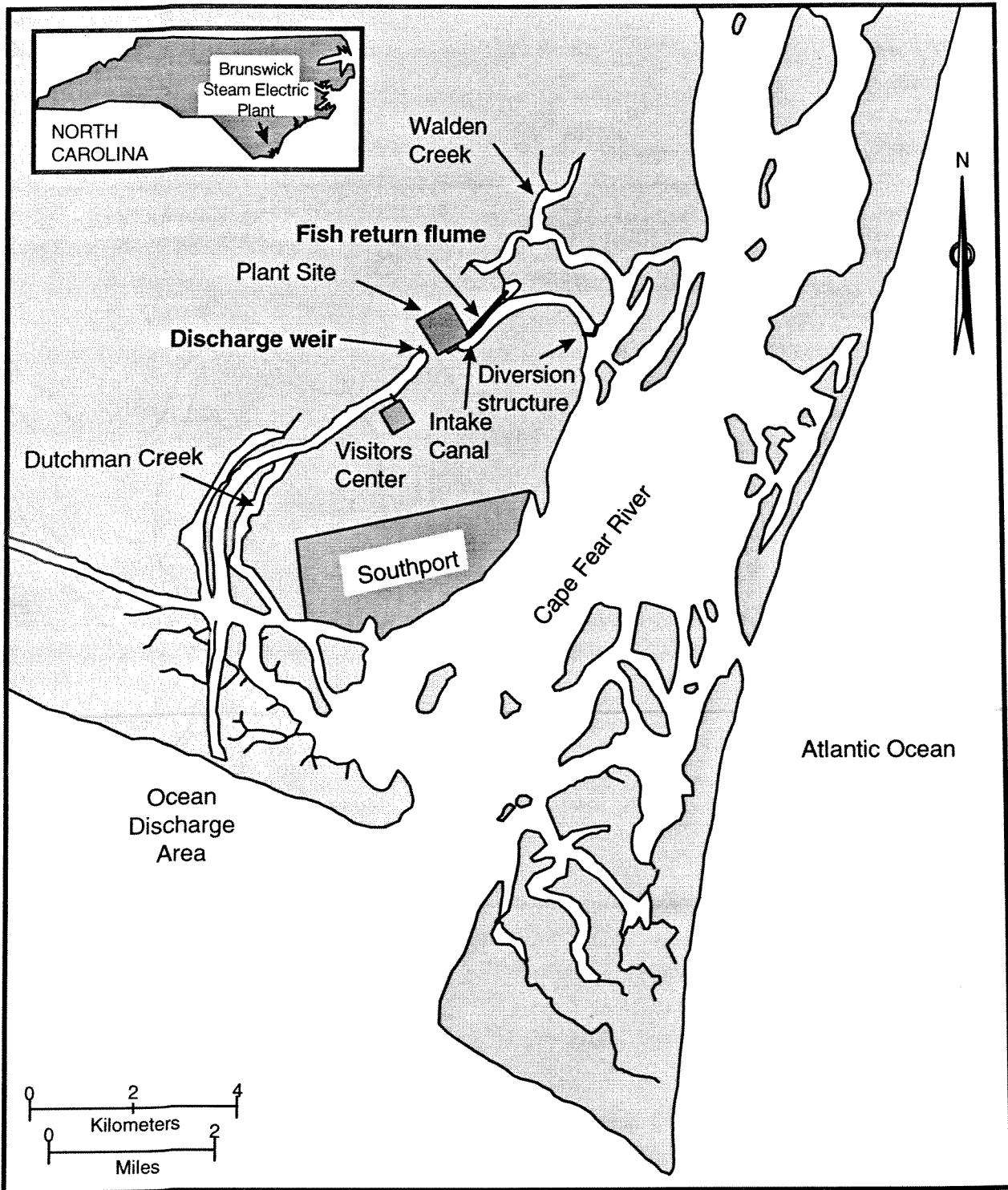
A stipulation of the renewed 1981 NPDES permit and subsequent permits was the implementation of power plant modifications to reduce entrainment and impingement of estuarine organisms resulting from the intake of cooling water. A permanent diversion structure was constructed across the mouth of the intake canal in November 1982 to reduce impingement by preventing large fish and shellfish from entering the intake canal (Figure 1.1). To reduce entrainment, fine-mesh (1-mm) screens were installed on two of the four intake traveling screen assemblies of each unit in July 1983 and a third was installed on each unit in April 1987. Presently, the NPDES permit requires that three of the four intake traveling-screen assemblies on each unit are covered with fine mesh screens.

Under the current permit, a maximum intake flow of 26.1 cubic meters per second (cms) per unit is allowed from December through March, and 31.1 cms per unit is allowed from April through November. Normally only fine-mesh screens are used during these periods of maximum intake flow. The flow of one unit may be increased to 34.8 cms during July, August, and September by using a fourth intake pump operating with coarse-mesh (9.4-mm) screens.

Beginning in 1994, Carolina Power & Light Company reduced the biological monitoring program with the concurrence of the North Carolina Department of Environment & Natural Resources. Based on almost two decades of operation with no adverse impact on fish and shellfish populations in the CFE, the monitoring program was modified to concentrate on the impingement and entrainment of organisms (Figure 1.2). This report presents 1999 data on impingement and entrainment rates of larval, juvenile, and adult fish and shellfish and evaluates the effectiveness of the NPDES-required plant intake modifications.



**Figure 1.1** Location of fish diversion structure, fish return system, and return basin at the BSEP.



**Figure 1.2** Impingement (fish return flume) and entrainment (discharge weir) sampling locations at the BSEP for 1999.

## 2.0 MONITORING PROGRAM RESULTS

### 2.1 Introduction

Past data indicated that the impingement of large fish and shellfish of the CFE has been reduced as a result of the 9.4-mm mesh screening on the diversion structure (CP&L 1984, 1985a, 1985b). Organisms small enough to enter the intake canal through the diversion structure may be impinged on the plant intake screens and returned to the CFE via a fish-return flume or they may be entrained through the plant. Previous studies by CP&L have documented a reduction in the entrainment of small organisms due to installation of fine-mesh screens at the intake structure and the subsequent survival of a percentage of impinged larvae returned to the CFE via the fish-return flume (Hogarth and Nichols 1981; CP&L 1989).

Entrainment sampling during 1999 documented the species composition, seasonality, and abundances of larval and postlarval organisms passing through the cooling system. Larval impingement sampling evaluated the success of the fine-mesh screens in reducing entrainment of these organisms. Juvenile and adult (J/A) impingement sampling documented species composition, densities, weights, and sizes of juvenile and adult organisms impinged during 1999 and provided evidence of the continued effectiveness of the diversion structure. Survival study results from previous years were used to determine the effectiveness of the return system at returning impinged organisms alive to the CFE (CP&L 1988).

During 1999, three hurricanes passed near the mouth of the CFE resulting in significant effects to the estuary. Hurricanes Dennis, Floyd, and Irene struck on August 29, September 15, and October 17, respectively. Freshwater discharge approached 100,000 cubic feet per second (cfs) in September and salinity in the intake canal remained at 0 parts per thousand (ppt) for a period of approximately three weeks (Figure 2.1).

### 2.2 Methods

The collection gear for entrainment and impingement has remained unchanged since 1984 (CP&L 1985a). Because sampling was conducted only once per month since 1990, results were not expanded to obtain annual estimates of organisms entrained or impinged; rather, entrainment and impingement rates, densities, and total number of organisms collected were expanded to give an estimate for 24 hours. The juvenile and adult impingement program included fish and shrimp  $\geq 41$  mm, portunid crabs  $\geq 25$  mm, and eels and pipefish  $\geq 101$  mm. Individuals smaller than these limits were included in the larval impingement program.

The densities calculated for all larval organisms from samples collected per sampling date were averaged to obtain a mean number per 1000 m<sup>3</sup> of water entrained through the plant. Densities for juvenile and adult organisms impinged on each sampling date were calculated by dividing the total number of organisms collected by the volume of water pumped through the plant. Densities were expressed as the number per million cubic meters of water pumped through the plant during each 24-hour sampling period.

Time-series analysis ( $\ln [\text{density} + 1]$ ) (CP&L 1985a) was performed on juvenile and adult impingement data from January 1977 through December 1999. Selected species included bay anchovy, Atlantic menhaden, croaker, spot, weakfish, southern flounder, brown shrimp, pink shrimp, white shrimp, and blue crabs (*Callinectes* spp.). The 1983 data were excluded from the analysis because impingement samples were not collected during July through December of that year. One sampling trip per month was used for all years for comparable sampling effort.

## 2.3 Results and Discussion

### 2.3.1 Dominant Species

As during previous years, *Gobiosoma* spp. was the most abundant taxa collected in entrainment samples during 1999 and comprised 37.7% of the cumulative density of all organisms collected (Table 2.1). Croaker (14.4%) was the second most abundant followed by spot and *Penaeus* spp. (12.6% and 8.2%, respectively). Other taxa entrained (in decreasing order of abundance) were *Anchoa* spp. (< 13 mm) portunid megalops, *Anchoa* spp. ( $\geq 13$  mm), *Gobionellus* spp., silversides and spotted seatrout. Minor taxa comprised an additional 5.5% of the total number of organisms collected. The cumulative density of total organisms collected in entrainment samples was approximately 20.4 % greater than that collected during 1998.

The total number of organisms collected in larval impingement samples decreased approximately 35.3% from the 17 million collected in 1998 (Table 2.2; CP&L 1999). Ten taxa accounted for 96.7% of the total larval organisms collected in impingement samples during 1999. Croaker (20.6%) was the most dominant taxa collected. Although the relative ranking has varied, the ten most abundant species have generally dominated larval impingement samples each year since 1984. The number of larval taxa collected in impingement samples was generally greater than the number collected in entrainment samples (Figure 2.2). Thus, use of one or more fine-mesh screens per unit reduced the number of taxa entrained by the plant's main cooling-water system.

Ten taxa accounted for 96.9% of the total number of organisms collected in J/A impingement samples during 1999 (Table 2.3). Bay anchovy was the most numerous species impinged accounting for 50.9% of the total number impinged during 1999. White shrimp was the second most abundant taxa impinged, accounting for 23.1% of the total number collected. Prior to intake modifications in 1983, Atlantic menhaden numerically dominated J/A impingement (CP&L 1980a, 1980b, 1982, 1983). Brown shrimp, blue crab, lesser blue crab, striped anchovy, star drum, spot, Atlantic menhaden, and threadfin shad combined accounted for an additional 22.9% of the total number collected. These ten most abundant taxa comprised 92.3% of the total weight collected during impingement sampling. Other taxa that contributed significantly to the biomass collected during J/A impingement sampling were southern flounder (4.9 kg), pinfish (4.1 kg), and oyster toadfish (3.0 kg). The total number of organisms collected in J/A impingement samples decreased by 27.7% in 1999 compared to the number in 1998 (Table 2.3; CP&L 1999). This reduction was likely a result of the high freshwater discharge associated with Hurricanes Dennis, Floyd, and Irene. BSEP personnel noticed the absence of organisms in the fish return system for two to three weeks immediately following Hurricane Floyd.

### 2.3.2 Seasonality and Abundance

The seasonality for the larvae of selected species entrained in 1999 was similar to those observed in previous years and corresponded to the seasonalities of larval fish in the estuary (Tables 2.4 and 2.5; CP&L 1994). Peaks of abundance in entrainment and impingement of organisms can be influenced by environmental conditions such as changing freshwater discharge to the estuary, operating screens without fine mesh, increasing or decreasing the flow of cooling water as determined by plant operational needs, and/or sampling period.

The typical winter and summer periods of abundance observed during 1999 in the entrainment program were also observed in the larval impingement program (Table 2.6). Atlantic menhaden, spot, croaker, and pinfish--all ocean-spawned species--were abundant during the winter and spring months. Brown shrimp was most abundant during the spring. During the late spring and summer, the larvae of ocean-spawned species (such as pink and white shrimp, spotted seatrout, and hardback shrimp) and estuarine-spawned species (such as anchovy, *Gobiosoma* spp., and silversides) were abundant. The period of abundance for portunid megalops occurred during the summer. Larval *Gobionellus* spp., present year-round, was most abundant during the fall. The large volume of freshwater discharge from the estuary during September resulting from three hurricanes (Figure 2.1) appeared to have flushed most fish, shrimp, and crab larvae from the estuary as witnessed by plant personnel sampling the fish return system. Few larvae were noted for the first two or three weeks after Hurricane Floyd. Once freshwater discharge returned to pre-Hurricane Floyd levels, the abundance and distribution of larvae in the estuary returned to normal as evidenced by large numbers of portunid megalops, croaker, and *Gobionellus* spp. collected while conducting larval impingement sampling during October (Table 2.6).

Results from J/A impingement sampling indicated two major periods of abundance for Atlantic menhaden (Table 2.7). Atlantic menhaden that were abundant during the winter were yearlings as indicated by modal lengths of 85 mm and 100 mm (Tables 2.7 and 2.8). During October, the majority of Atlantic menhaden impinged were young-of-year individuals. Peak densities of croaker during April and May and spot during May were associated with the recruitment of young-of-year individuals too small to be excluded by the diversion structure as evidenced by the small modal lengths of fish collected during those months. Bay anchovy was most abundant from January through April (Table 2.7). The peak densities of white, brown, and pink shrimp occurred during the summer and fall. Blue crab was abundant during summer. These patterns of abundance were consistent with previous years.

Installation of the diversion structure has resulted in a decline in the impingement densities of most J/A organisms. Results of time-series analysis indicated that total organisms and nine of the ten selected taxa exhibited significant decreases in impingement density over the past 23 years (Table 2.9). Atlantic menhaden exhibited the greatest decline in impingement density (Figure 2.3). White shrimp was the only species which exhibited a significant increase in density over the study period (Table 2.9 and Figure 2.4). The trend was a result of a natural increase in white shrimp populations in the Cape Fear Estuary. Previous studies have shown that significant increases in the white shrimp population in Walden Creek coincide with increases in impingement of this species (CP&L 1994). Postlarval shrimp too small to be excluded by the

diversion structure successfully recruited to the intake canal and used it as nursery habitat and were subsequently impinged (Birkhead et al. 1979; Copeland et al. 1974, 1979; CP&L 1991).

### 2.3.3 Flow Rates

The amount of water pumped through the plant can affect the number and weight of organisms impinged and entrained. Monthly intake flow volumes during 1999 ranged from 113 million m<sup>3</sup> in May to 176 million m<sup>3</sup> in July (Figure 2.5). The mean monthly flow volume during 1999 was higher than the mean flows of previous years including the period 1977-1982 when there were less stringent flow-minimization requirements. The greater monthly volumes during 1999 were a result of the significantly reduced time required for outages resulting in more continuous plant operation. The low monthly volume during May was a result of the Unit 2 refueling outage.

### 2.3.4 Fine-Mesh Screens

In 1999, entrainment and larval impingement rates were summed to find the total number of larvae affected. The percent effectiveness (how successfully the organisms were kept from being entrained) of fine-mesh screens was calculated as the ratio between the larval impingement rate and the total number (entrainment plus larval impingement) affected for each sampling trip. The overall effectiveness for total organisms ranged from 2% to 39% when data from all sampling trips were analyzed (Table 2.10). These efficiencies were less than reported for 1998 (7% to 58%). Previous studies have shown that the operation of three fine-mesh screens per unit versus no fine-mesh screens may reduce the total mean density of entrained organisms by 61% (CP&L 1989; 1998).

The reduced efficiencies were a result of operation of one or more coarse-mesh traveling screens and some screens with 50% of the fine-mesh panels removed during the latter portion of the year (Table 2.11). On June 28, the plant experienced multiple cooling water intake pump trips and a scram of the unit 2 reactor due to excessive detritus and mud buildup on the fine-mesh traveling screens. As a result, 50% of the fine-mesh screen panels were removed from two traveling screens on unit 1 and three traveling screens on unit 2. The North Carolina Department of Environment and Natural Resources was subsequently notified regarding the status of the fine-mesh screens. In addition, one or more coarse-mesh traveling screens were operated on each unit during the remainder of the year. By November, nearly all of the fine-mesh traveling screens had been restored but additional pump trips occurring on November 9 required the removal of some fine-mesh screen panels (Table 2.11). The root cause of the detritus and mud accumulation on the traveling screens during both events was extreme low tides coupled with increased sedimentation (due to recurring hurricanes in recent years) resulting in shoaling of the intake canal. Results of fathometer surveys indicated that sedimentation rates had increased substantially due to the three hurricanes that made landfall in the area during August and September.

In addition to the number of fine-mesh screens operating, the variability of effectiveness was influenced by species composition, seasonality, and organism size. Body size and shape have been shown to have an effect on screening efficiency for other species of larval fish

(Tomljanovich et al. 1978; Stone & Webster Engineering Corporation 1984). During January-June and October when fine-mesh screen efficiencies were highest, no or fewer coarse-mesh screens were operating and the dominant larvae were croaker, spot, Atlantic menhaden, *Anchoa* spp. ( $\geq 13$  mm), *Penaeus* spp. and portunid megalops, (taxa exhibiting relatively high fine-mesh screen efficiency) (Tables 2.5 and 2.6). The lowest fine-mesh screen efficiencies for the year were recorded during July through September and again in November when one or more coarse-mesh screens were operating (Table 2.10). Despite the operation of less fine-mesh traveling screens during 1999, the number of larval taxa impinged was still greater than the number entrained for most months of the year (Figure 2.2).

### 2.3.5 Survival Estimates

Survival was determined for selected size classes of the dominant organisms that have been impinged at the BSEP in past years (CP&L 1985a, 1986, 1987, 1988). Screens were operated on slow-screen rotation speed (75 cm/min) for most sampling dates in 1999. Survival calculations were calculated using survival rates determined during previous studies for slow-screen rotation (CP&L 1988). A mortality rate of 100% is used for taxa that have never been tested. Thus, the estimated survival rate for total organisms is a conservative and minimum estimate.

Seven taxa of the dominant larvae impinged were previously tested for survival on slow screen rotation speed (Table 2.12). These seven taxa accounted for about 46.3% of the total larval impingement catch. Survival during slow-screen rotation ranged from 0% for Atlantic menhaden to 86.3% for portunid megalops. Approximately 48.3% of the selected organisms were returned alive to the estuary. Estimates indicated that approximately 22.4% of all the larval taxa impinged were returned to the estuary alive. The overall larval survival rate decreased from 1998 due to the decrease in the number of portunid megalops and *Penaeus* spp; impinged during 1999.

Six taxa of the dominant J/A organisms impinged were previously tested for survival during slow-screen rotation (Table 2.13). These taxa accounted for 93.7% of the total number collected and 86.5% of the total weight collected. Excluding bay anchovy, survival ranged from 53.1% for croaker to 92.1% for blue crabs. The most valuable commercial species (shrimp and blue crabs) exhibited the highest survival rates. Survival estimates indicated that 76.0% of the total number and 73.4% of the total weight of the selected J/A organisms impinged, excluding bay anchovy, were returned alive to the estuary during 1999. These percentages were higher than reported for 1997 (34.1% and 36.2%, respectively) since larger J/A penaeid shrimp and blue crabs comprised the majority of the larger organisms impinged during 1999 once bay anchovy is excluded from the analysis (Table 2.3; CP&L 1998).

## 2.4 Summary and Conclusions

Seasonality of organisms collected in the 1999 entrainment and larval impingement studies were similar to previous years and corresponded to the seasonalities of larval organisms in the estuary. *Gobiosoma* spp. was the most abundant organism collected in entrainment samples whereas croaker was the most abundant organism collected in larval impingement samples. The total mean density of organisms collected in entrainment samples increased approximately 20%

from that collected in 1998. The total number of larval organisms collected in impingement samples decreased by 35% from the total number in 1998.

Use of fine-mesh screens reduced the number of larval organisms and the number of larval taxa entrained. The number of taxa collected during entrainment sampling was reduced by 21 from a total of 55 taxa impinged. All 55 taxa would have been entrained without use of fine-mesh traveling screens. Depending upon taxa, entrainment of all organisms was reduced by approximately 19% with a range of 2% to 39% by using fine-mesh screens in 1999. Reductions in the entrainment of organisms during 1999 were less than previous years due to operation of a greater number of coarse-mesh screen panels. Adverse effects on populations of fish and shellfish due to operation of fewer fine-mesh screens during a portion of the year was most likely minimal. Results of intensive sampling throughout the 1970's, before the installation of fine-mesh screens and the fish return system, indicated that operation of the plant had no measurable adverse effect on fish and shellfish populations in the Cape Fear River Estuary (CP&L 1980a). Annual population levels were determined by temperature, freshwater flow, and salinity (CP&L 1980a). Based on survival estimates data, approximately 22% of all larval species impinged were returned alive to the estuary. Fewer shrimp and crab larvae (taxa exhibiting high survival in the fish return system) were impinged during 1999 resulting in lower overall survival compared to 1998. The lower number of shrimp and crab larvae impinged was the result of using fewer fine-mesh screens after June when shrimp and crab larvae are more abundant coupled with the temporary effects of three hurricanes hitting the area during late summer and fall.

Recurring hurricanes and associated increased sedimentation rates during recent years have contributed to operability problems with the fine-mesh traveling screens. There has been the occurrence of several periods of cooling water pump trips including one reactor scram during late June 1999 which required the removal of some fine-mesh screen panels. Dredging of the intake canal is underway in an effort to restore full operability of the fine-mesh traveling screens.

The 1999 juvenile and adult impingement catch was numerically dominated by bay anchovy and white shrimp. Prior to 1983, larger finfish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 1999 continued to show a shift towards impingement of smaller individuals for most of the selected species as a result of the construction of the diversion structure and the use of fine-mesh screens. This is important because it is the larger individuals which comprise the reproducing members of the population. Results of time-series analysis on 23 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Ten out of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities from 1977 through 1999. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline. Based on survival estimates, approximately 76% of the total number and 73% of the total weight of the impinged organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the blue crabs and approximately 87% to 94% of the shrimp were returned alive to the estuary. These were the most valuable commercial species.

Modifications made to the Brunswick Steam Electric Plant intake continued to be effective in reducing the number of organisms affected by the withdrawal of cooling water from the Cape

Fear Estuary. The diversion structure excluded most large organisms. A percentage of the larval, juvenile, and adult organisms impinged were returned alive to the estuary by using fine-mesh traveling screens and the fish return system.

**Table 2.1** Cumulative density (No./1000 m<sup>3</sup>) and percent of total for fish, penaeid shrimp, and portunid megalops collected during entrainment sampling at the BSEP during 1998 and 1999 (based on ranking for 1999).

Taxon	1998		1999	
	Cumulative <sup>+</sup> density	Percent	Cumulative <sup>+</sup> density	Percent
<i>Gobiosoma</i> spp. ✓	2,053	28.2	3,308	37.7
Croaker ✓	1,259	17.3	1,267	14.4
Spot ✓	723	9.9	1,101	12.6
<i>Penaeus</i> spp. ✓	661	9.1	715	8.2
<i>Anchoa</i> spp. (<13 mm) ✓	369	5.1	610	7.0
Portunid megalops ✓	440	6.0	404	4.6
<i>Anchoa</i> spp. (≥ 13 mm) ✓	469	6.4	326	3.7
<i>Gobionellus</i> spp. ✓	289	4.0	247	2.8
Silversides ✓	137	1.9	207	2.4
Spotted seatrout ✓	19	0.3	110	1.3
Other taxa	871	12.0	479	5.5
<b>Total<sup>¶</sup></b>	<b>7,290</b>	<b>100.0</b>	<b>8,774</b>	<b>100.0</b>

<sup>+</sup> Cumulative density is the sum of the twelve sampling -day mean densities.

<sup>¶</sup> Total may vary from summation due to rounding of individual taxon.

**Table 2.2** Total number of selected taxa estimated by larval impingement sampling at the BSEP during 1999, ranked by percent.

Taxon	Total number <sup>+</sup>	Percent
Croaker	$2.3 \times 10^6$	20.6
<i>Penaeus</i> spp.	$1.7 \times 10^6$	15.2
Spot	$1.7 \times 10^6$	15.1
<i>Gobiosoma</i> spp.	$1.4 \times 10^6$	12.8
Portunid megalops	$1.1 \times 10^6$	10.2
<i>Anchoa</i> spp. (<13 mm)	$1.0 \times 10^6$	9.2
<i>Gobionellus</i> spp.	$8.1 \times 10^5$	7.2
<i>Anchoa</i> spp. ( $\geq 13$ mm)	$5.5 \times 10^5$	4.9
Atlantic menhaden	$1.0 \times 10^5$	0.9
Silver perch	$7.0 \times 10^4$	0.6
Other taxa	$3.8 \times 10^5$	3.3
<b>Total<sup>¶</sup></b>	<b><math>1.1 \times 10^7</math></b>	<b>100.0</b>

<sup>+</sup>Total number is a sum of the twelve sampling-day totals.

<sup>¶</sup>Total may vary from summation due to rounding of individual taxon.

**Table 2.3** Total number, total weight, and percent of total of the ten most abundant juvenile and adult organisms collected in the BSEP impingement samples during 1999.

Taxon	Number <sup>+</sup>	Percent <sup>¶</sup>	Weight (kg) <sup>+</sup>	Percent <sup>¶</sup>
Bay anchovy ✓	79,988	50.9	89.2	14.3
White shrimp ✓	36,311	23.1	237.0	38.0
Brown shrimp ✓	20,650	13.1	77.6	12.4
Blue crab ✓	3,550	2.3	105.6	16.9
Lesser blue crab	3,466	2.2	8.1	1.3
Striped anchovy	2,616	1.7	14.7	2.4
Star drum	1,857	1.2	7.3	1.2
Spot ✓	1,856	1.2	12.8	2.0
Atlantic menhaden ✓	949	0.6	19.2	3.1
Threadfin shad	934	0.6	4.3	0.7
Other taxa	4,948	3.1	48.3	7.7
<b>Total</b>	<b>157,125</b>	<b>100.0</b>	<b>624.1</b>	<b>100.0</b>

<sup>+</sup>Numbers and weights are sums of the twelve sampling day totals.

<sup>¶</sup>Percentages may not add up to 100 due to rounding.

**Table 2.4**      Entrainment densities (mean no./1000 m<sup>3</sup> per sampling day) of selected taxa<sup>+</sup> at the BSEP during 1999.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid megalops	3	0	6	0	3	11	24	47	23	108	99	80
<i>Penaeus</i> spp.	69	0	25	58	39	40	58	76	240	24	48	40
Croaker	36	45	3	3	5	0	0	0	0	702	285	0
Anchoa spp. (<13 mm)	0	0	0	0	3	429	140	26	13	0	0	0
Anchoa spp. (≥ 13 mm)	71	6	19	0	3	41	33	5	159	30	3	0
Spot	211	293	371	189	45	0	0	0	0	0	0	4
<i>Gobionellus</i> spp.	3	9	6	15	5	6	33	23	11	107	27	4
<i>Gobiosoma</i> spp.	0	0	0	0	23	783	2,086	276	145	0	0	0
Silversides	0	0	0	161	46	0	0	0	0	0	0	0
Atlantic menhaden	6	9	11	3	0	0	0	0	0	0	0	0
Spotted seatrout	0	0	0	0	0	107	0	3	0	0	0	0
<b>Total organisms</b>	<b>396</b>	<b>383</b>	<b>443</b>	<b>462</b>	<b>202</b>	<b>1,537</b>	<b>2,413</b>	<b>506</b>	<b>662</b>	<b>971</b>	<b>479</b>	<b>321</b>

<sup>+</sup>Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

**Table 2.5**      **Entrainment rates (million per sampling day) of selected taxa<sup>+</sup> at the BSEP during 1999.**

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid megalops	0.013	0	0.027	0	0.007	0.061	0.135	0.268	0.128	0.583	0.532	0.363
<i>Penaeus</i> spp.	0.312	0	0.111	0.309	0.105	0.217	0.328	1.366	1.366	0.127	0.260	0.179
Croaker	0.163	0.202	0.014	0.015	0.014	0	0	0	0	3.776	1.531	0
Anchoa spp. ( $< 13$ mm)	0	0	0	0	0.007	2.308	0.796	0.149	0.074	0	0	0
Anchoa spp. ( $\geq 13$ mm)	0.320	0.028	0.085	0	0.007	0.219	0.190	0.028	0.909	0.161	0.016	0
Spot	0.952	1.323	1.672	1.018	0.121	0	0	0	0	0	0	0.017
<i>Gobionellus</i> spp.	0.013	0.039	0.028	0.078	0.014	0.031	0.186	0.301	0.060	0.576	0.143	0.017
<i>Gobiosoma</i> spp.	0	0	0	0	0.062	4.217	11.894	1.572	0.826	0	0	0
Silversides	0	0	0	0.869	0.122	0	0	0	0	0	0	0
Atlantic menhaden	0.026	0.041	0.047	0.015	0	0	0	0	0	0	0	0
Spotted seatrout	0	0	0	0	0	0.576	0	0.019	0	0	0	0
<b>Total organisms</b>	<b>1.786</b>	<b>1.728</b>	<b>1.998</b>	<b>2.489</b>	<b>0.542</b>	<b>8.274</b>	<b>13.757</b>	<b>2.886</b>	<b>3.776</b>	<b>5.224</b>	<b>2.577</b>	<b>1.502</b>
<b>Volume (<math>\times 10^6</math> m<sup>3</sup>)</b>	<b>4.512</b>	<b>4.512</b>	<b>4.512</b>	<b>5.383</b>	<b>2.692</b>	<b>5.383</b>	<b>5.701</b>	<b>5.701</b>	<b>5.701</b>	<b>5.383</b>	<b>5.383</b>	<b>4.512</b>

<sup>+</sup>Selected taxa comprised  $\geq 1\%$  of the total sampled in either entrainment or larval impingement.

**Table 2.6** Total number (million per sampling day) of selected taxa<sup>+</sup> estimated by monthly samples of larval impingement at the BSEP during 1999.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Portunid megalops	0.038	0	0	0.017	0.001	0.218	0.007	0.052	0.011	0.647	0.033	0.078
<i>Penaeus</i> spp.	0	0.027	0.068	0.102	0.028	1.161	0.010	0.024	0.045	0.115	0.025	0.102
Croaker	0.095	0.149	0.030	0.008	0.003	0	0	0 < 0.001		1.635	0.135	0.258
Anchoa spp. (< 13 mm)	0	0	0	0	0.002	1.003	0.028	0.002 < 0.001		0	0	0
Anchoa spp. (≥ 13 mm)	0.149	0.041	0.033	0.005	< 0.001	0.076	0.005	< 0.001	0.015	0.223	0.002	0.001
Spot	0.246	0.458	0.730	0.245	0.016	0	0	0	0	0	0	0
<i>Gobionellus</i> spp.	0.004	0.021	0.005	0.003	0.001	0.002	0.003	0.001	0.001	0.757	0.010	0.002
<i>Gobiosoma</i> spp.	0	0	0	0	0.002	1.007	0.428	0.003	0.004	0	0	0
Silversides	0	0	0 < 0.001	0.002	0.003	0	0	0	0	0	0	0
Atlantic menhaden	0.005	0.035	0.020	0.043	0	0	0	0	0	0	0	0.001
Spotted seatrout	0	0	0	0	0	0.027	< 0.001	0 < 0.001		0	0	0
<b>Total organisms</b>	<b>0.554</b>	<b>0.763</b>	<b>0.939</b>	<b>0.456</b>	<b>0.078</b>	<b>3.708</b>	<b>0.487</b>	<b>0.101</b>	<b>0.086</b>	<b>3.422</b>	<b>0.209</b>	<b>0.453</b>

<sup>+</sup>Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

**Table 2.7** Juvenile and adult impingement densities (No./million m<sup>3</sup> of water entrained during each 24-hour sampling period) for selected species<sup>+</sup> and the number of damaged diversion screens per month at the BSEP during 1999.

Month	Bay anchovy	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp	Blue crab	Damaged Screens
Jan	2,479	36	68	10	42	0	20	3	0
Feb	4,304	50	13	17	39	0	38	62	4
Mar	2,770	17	24	3	46	0	0	28	2
Apr	4,858	13	8	58	61	1	5	88	7
May	525	5	165	39	4	0	1	88	0
Jun	510	7	73	10	23	3,703	0	522	18
Jul	2	< 1	2	< 1	33	76	0	15	2
Aug	4	< 1	1	0	160	41	36	50	9
Sep	< 1	7	22	2	1,237	< 1	31	159	5
Oct	904	56	6	12	4,349	7	5	168	7
Nov	182	2	3	< 1	491	0	1	95	10
Dec	407	5	75	2	211	0	1	81	9

<sup>+</sup>Selected species, with the exception of bay anchovy are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

**Table 2.8** Modal lengths (mm) for selected<sup>+</sup> juvenile and adult impingement species<sup>¶</sup> collected by month at the BSEP during 1999.

Month	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp
Jan	100	65	65	100	NC <sup>§</sup>	45
Feb	85	80	60	90	NC	70
Mar	85	80	60,75	105	NC	NC
Apr	105	90	45	130	ID	ID
May	150	45	55	ID	NC	ID
Jun	130	45	ID	150-155	80	NC
Jul	ID	55	ID	55	105	NC
Aug	ID	65	NC	70	100	55
Sep	50	65	ID	95	ID	55
Oct	75	90	130	100	ID	ID
Nov	85	65,75	ID	110	NC	ID
Dec	75	75	ID	120	NC	ID

<sup>+</sup>Selected species are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

<sup>¶</sup>Fish  $\geq 41$  mm and crabs  $\geq 25$  mm.

<sup>§</sup>NC= None Collected.

<sup>£</sup>ID = Insufficient number collected ( $< 10$ ).

**Table 2.9** Time-series analysis of BSEP juvenile and adult impingement data indicating trends in density from January 1977 through December 1999.

<b>Taxon</b>	<b>Trend<sup>+</sup></b>	<b>Slope</b>	<b>R<sup>2</sup></b>
Atlantic menhaden	—***	—0.00044	0.97
Weakfish	—***	—0.00026	0.97
Blue crabs	—***	—0.00021	0.96
Spot	—***	—0.00021	0.96
Croaker	—***	—0.00022	0.96
Southern flounder	—***	—0.00016	0.96
Pink shrimp	—***	—0.00017	0.96
Bay anchovy	—***	—0.00008	0.98
Brown shrimp	—**	—0.00006	0.97
White shrimp	+***	0.00033	0.98
<b>Total organisms</b>	<b>—***</b>	<b>—0.00015</b>	<b>0.96</b>

<sup>+</sup>Trends are explained with the following notation:

NS =  $P > 0.05$

\* =  $0.01 < P \leq 0.05$

\*\* =  $0.001 < P \leq 0.01$

\*\*\* =  $P \leq 0.001$

+ = Increasing trend

— = Decreasing trend

R<sup>2</sup> = Amount of variation explained by the dependent variable in the time-series model.

**Table 2.10** Percent effectiveness of fine-mesh screens in reducing the number of selected taxa entrained per sampling day at the BSEP during 1999.

Taxa	Month												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
Portunid megalops	75	NP <sup>+</sup>	0	100	13	78	5	16	8	53	6	18	34
<i>Penaeus</i> spp.	0	100	38	25	21	84	3	2	3	48	9	36	27
Croaker	37	42	68	36	17	NP	NP	NP	100	30	8	100	29
<i>Anchoa</i> spp. ( $< 13$ mm)	NP	NP	NP	NP	20	30	3	1	$< 1$	NP	NP	NP	24
<i>Anchoa</i> spp. ( $\geq 13$ mm)	32	59	28	100	6	26	3	1	2	58	13	100	22
Spot	21	26	30	19	12	NP	NP	NP	NP	NP	NP	0	25
<i>Gobionellus</i> spp.	24	35	15	4	4	7	2	1	1	57	6	9	38
<i>Gobiosoma</i> spp.	NP	NP	NP	NP	4	20	4	$< 1$	$< 1$	NP	NP	NP	7
Silversides	NP	NP	NP	0	2	100	NP	NP	NP	NP	NP	NP	$< 1$
Atlantic menhaden	16	46	30	74	NP	NP	NP	NP	NP	NP	NP	100	44
Spotted Seatrout	NP	NP	NP	NP	NP	5	100	0	100	NP	NP	NP	4
<b>Total Organisms</b>	<b>23</b>	<b>30</b>	<b>32</b>	<b>16</b>	<b>10</b>	<b>32</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>39</b>	<b>8</b>	<b>24</b>	<b>19</b>

\*NP = Not Present.

**Table 2.11** Number of main cooling-water pumps and fine-mesh screens operating by sampling trip<sup>+</sup> at the BSEP during 1999.

Month	Number of pumps	Number of Fine-mesh traveling screens
January	6	All fine mesh
February	6	All fine mesh
March	6	All fine mesh
April	6	All fine mesh except for operation of 1 coarse-mesh for 12 hours <sup>¶</sup> .
May	3	2 fine mesh & 1 coarse mesh (Unit 2 refueling outage) <sup>¶</sup>
June <sup>§</sup>	6	All fine mesh except for operation of a coarse-mesh for 12.3 hours <sup>¶</sup>
July	7	2 coarse mesh & 5 remaining screens with 50% fine mesh
August	7	2 coarse mesh & 5 remaining screens with 50% fine mesh
September	7	2 coarse mesh & 5 remaining screens with 50% fine mesh
October	6	1 coarse mesh, 2 fine mesh, & 3 remaining screens with 50% fine mesh
November <sup>§</sup>	6	3 coarse mesh, 2 fine mesh, & 1 remaining screen with 50% fine mesh
December	6	3 fine mesh, 3 coarse mesh

<sup>+</sup>Fine-mesh screen configurations represent those in effect during the 24-hour sampling trip.

<sup>¶</sup>The NPDES permit allows for a fine-mesh traveling screen to be switched with a coarse-mesh screen for routine maintenance.

<sup>§</sup>Multiple cooling-water pump trips occurred during these months due to mud and detritus accumulation on the fine-mesh traveling screens.

**Table 2.12** Estimated number and percent survival of selected larval organisms collected during impingement sampling at the BSEP during 1999.

<b>Taxon</b>	<b>Number collected</b>	<b>Percent survival<sup>+</sup></b>	<b>Number survived<sup>¶</sup></b>
Croaker	2,313,504	14.4	333,145
<i>Penaeus</i> spp.	1,707,984	80.3	1,371,511
Spot	1,695,168	9.0	152,565
Portunid megalops	1,145,808	86.3	988,832
Atlantic menhaden	103,104	0.0	0
<i>Anchoa</i> spp. ( $\geq 13$ mm)	550,800	0.3	1,652
Hardback shrimp	5,616	48.4	2,718
<b>Total selected taxa</b>	<b>5,208,480</b>	<b>48.3</b>	<b>2,517,279</b>
<b>Total all taxa<sup>§</sup></b>	<b>11,255,328</b>	<b>22.4</b>	<b>2,517,279</b>

<sup>+</sup>Reference: CP&L 1988 (slow-screen rotation).

<sup>¶</sup>The number survived is a total for the 12 sampling days and not the entire year.

<sup>§</sup>Survival estimate is for all taxa including those not tested for survival during slow-screen rotation. This estimate is very conservative in that 100% mortality is assumed for taxa not tested. In reality, many of these individuals survived.

**Table 2.13** Estimated number, weight (kg), and percent survival of selected juvenile and adult organisms collected during impingement sampling at the BSEP during 1999.

<b>Taxon</b>	<b>Number collected</b>	<b>Weight collected</b>	<b>Percent survival<sup>+</sup></b>	<b>Number<sup>¶</sup> survived</b>
Shrimp (pink and white)	37,017	238.7	86.5	32020
Bay anchovy	79,988	89.2	1.1	880
Spot	1,856	12.8	57.1	1060
Blue crabs	7,016	113.6	92.1	6462
Brown shrimp	20,650	77.6	90.7	18,730
Croaker	691	7.7	53.1	367
<b>Total</b>	<b>147,318</b>	<b>539.6</b>		<b>59518</b>
<b>Percent survival<sup>§</sup> (all species)</b>	<b>37.9% by number</b>	<b>63.1% by weight</b>		
<b>Percent survival<sup>§</sup> (all species excluding bay anchovy)</b>	<b>76.0% by number</b>	<b>73.4% by weight</b>		<b>58638</b>

<sup>+</sup>Reference: CP&L 1988 (Slow-screen rotation).

<sup>¶</sup>The number survived is a total for the 12 sampling days and not the entire year.

<sup>§</sup>Survival estimate is for all taxa including those not tested for survival during slow-screen rotation. This estimate is very conservative in that 100% mortality is assumed for taxa not tested. In reality, many of these individuals survived.

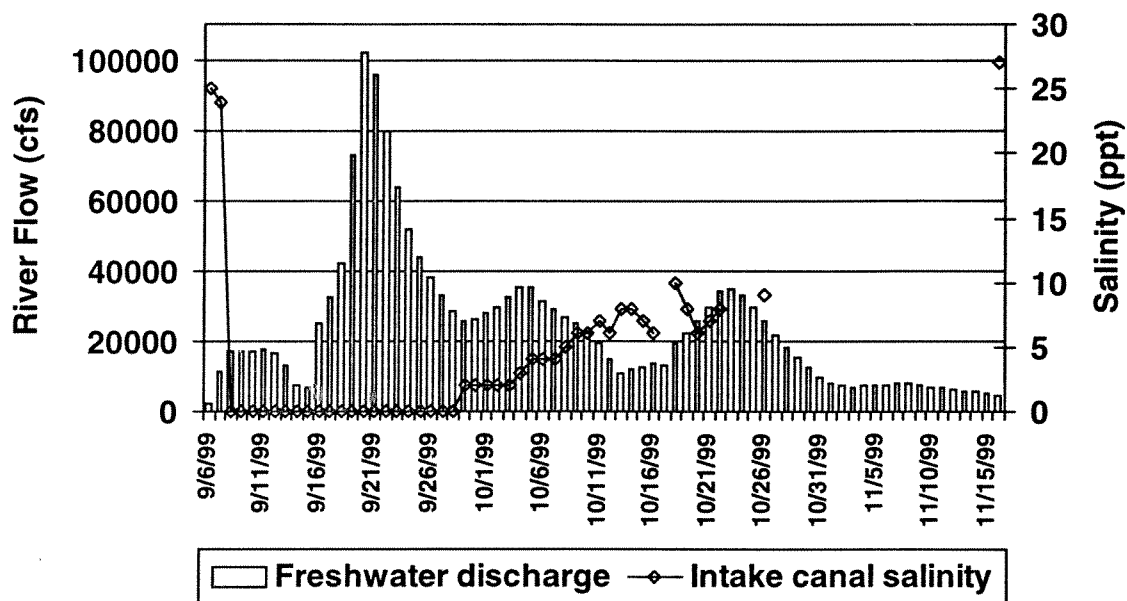


Figure 2.1 Mean daily freshwater discharge from the Cape Fear River and intake canal salinity at the BSEP from September 6 to November 16, 1999.

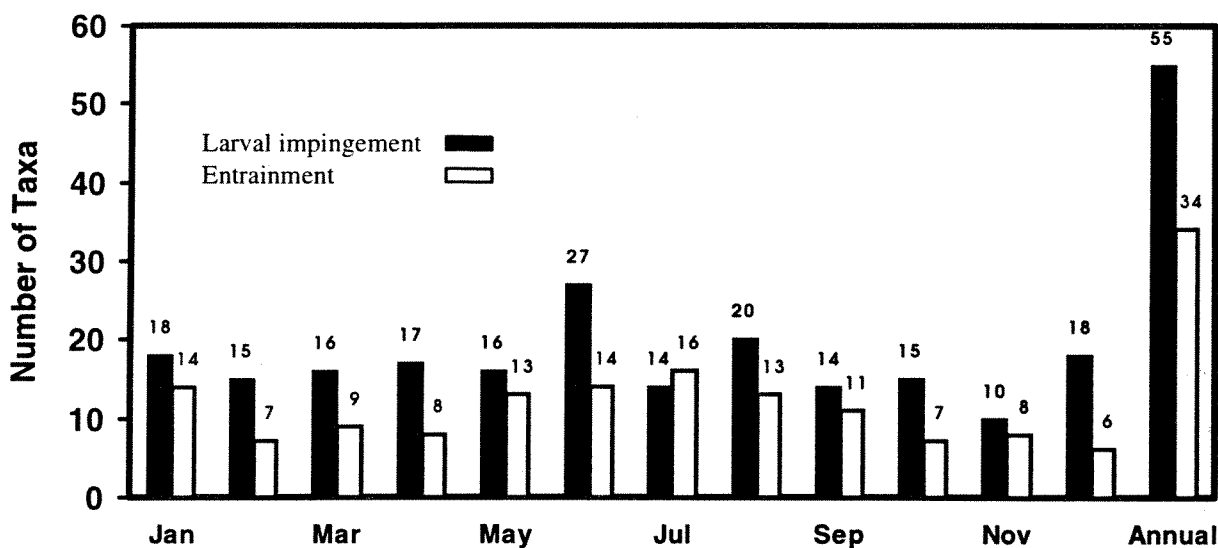


Figure 2.2 Number of taxa collected in entrainment and larval impingement samples at the BSEP during 1999.

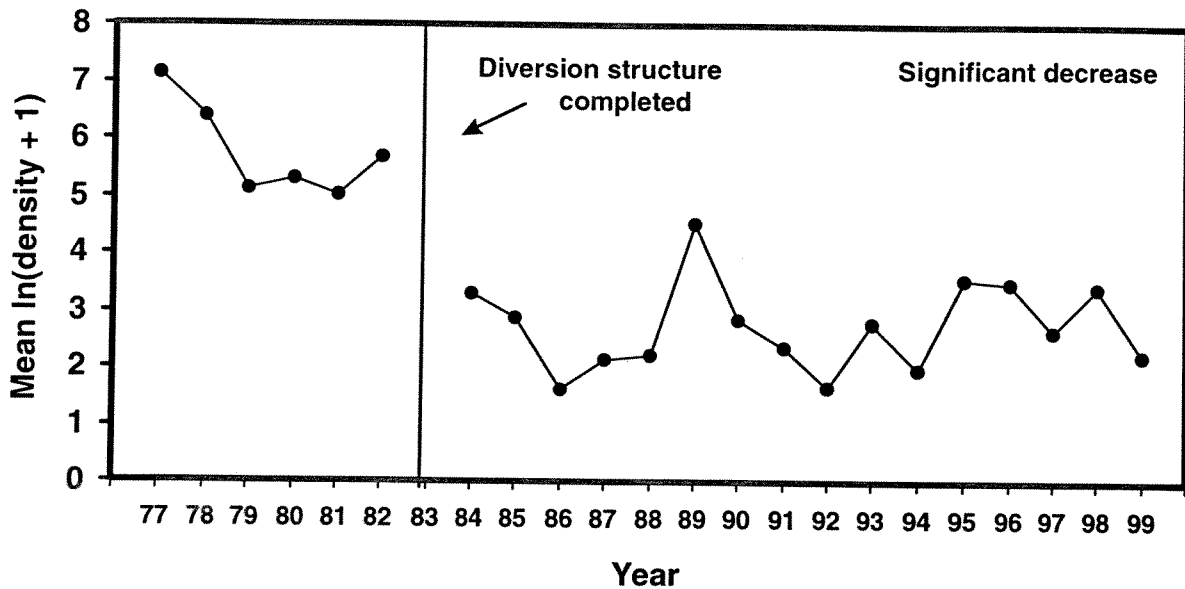


Figure 2.3 Time-series analysis of juvenile and adult Atlantic menhaden data collected during impingement sampling at the BSEP from 1977 through 1999.

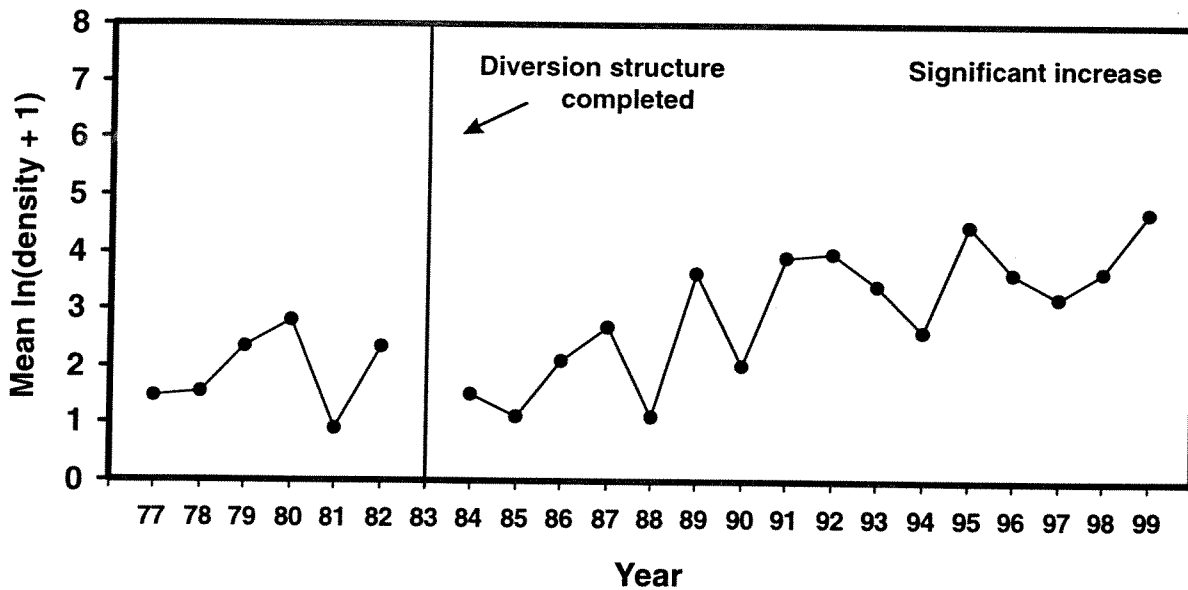


Figure 2.4 Time-series analysis of juvenile and adult white shrimp data collected during impingement sampling at the BSEP from 1977 through 1999.

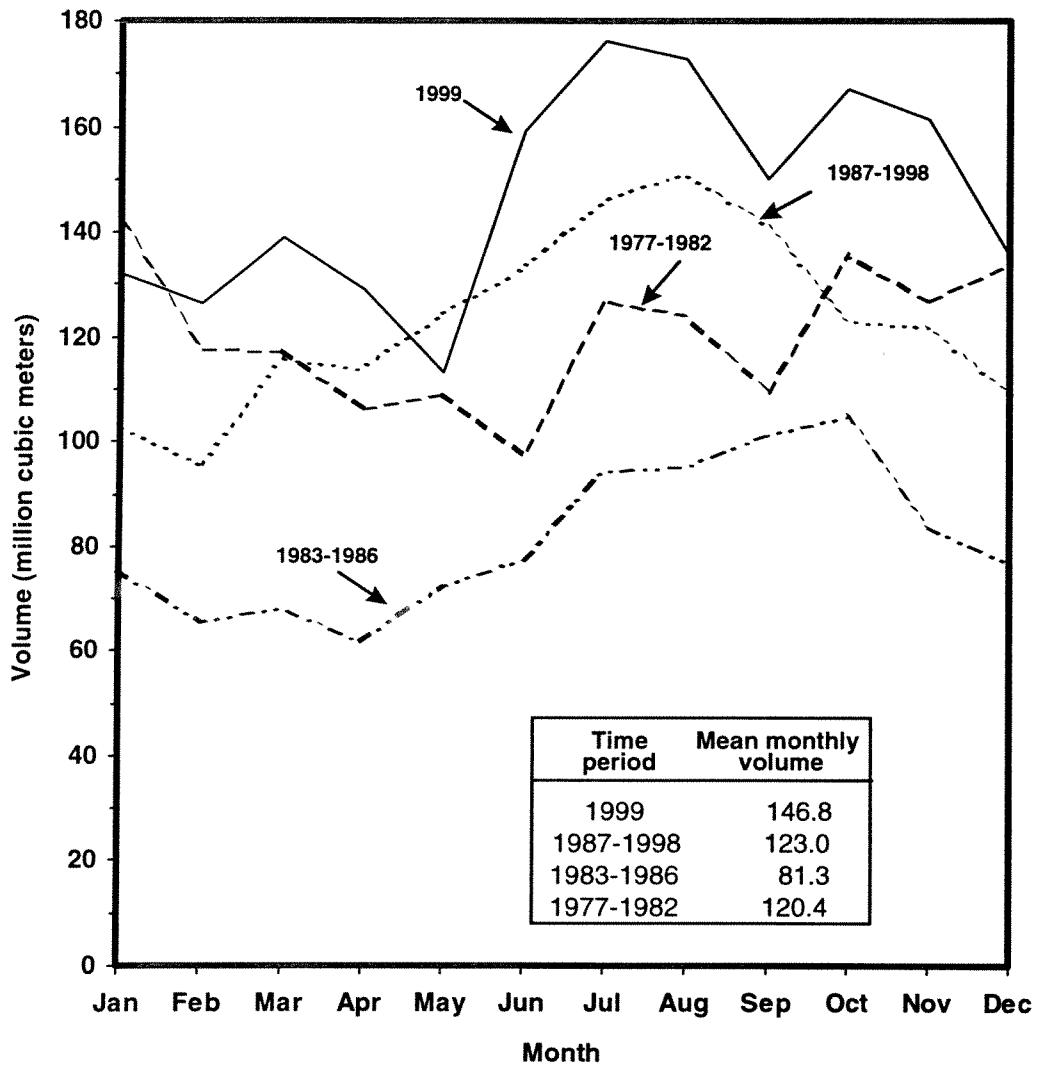


Figure 2.5 Monthly flow (million cubic meters) of water pumped at the BSEP from 1977 through 1999.

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